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Memorandum of Project MICHIGAN

RESPONSE BIAS EXPLANATION OF WORD-FREQUENCY EFFECT

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Institute of Science and Technology
THE UNIVERSITY OF MICHIGAN

April 1963

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PREFACE

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The emphasis of the Project is upon research in imaging radar, MTI radar, infrared, radio location, image processing, and special investigations. Particular attention is given to all-weather, long-range, high-resolution sensory and location techniques.

Project MICHIGAN was established by the U. S. Army Signal Corps at The University of Michigan in 1953 and has received continuing support from the U. S. Army. The Project constitutes a major portion of the diversified program of research conducted by the Institute of Science and Technology in order to make available to government and industry the resources of The University of Michigan and to broaden the educational opportunities for students in the scientific and engineering disciplines.

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Progress and results described in reports are continually reassessed by Project MICHIGAN. Comments and suggestions from readers are invited.

Robert L. Hess
Director
Project MICHIGAN

RESPONSE BIAS EXPLANATION OF WORD-FREQUENCY EFFECT

ABSTRACT

The word-frequency effect observes that, when presented in equally noisy conditions, words occurring more frequently in the language are identified correctly more often than words occurring less frequently. The response bias explanation avers that this finding is due solely to the tendency to respond more frequently with the common, or more frequent, words.

In a test of this explanation of word-frequency effect, printed five-letter words with letter deletions simulating different noisy conditions were used. The results show that a response bias model denying stimuli any role accounts for practically all of the variance in the word-frequency effect at high noise levels. The model, however, is internally restricted, and its efficiency is artifactual. Another formulation, based on the Brown and Rubenstein model, will be tested in a future experiment. This new formulation is multiplicative instead of additive, and is no longer internally restricted.

A response bias model developed by Brown and Rubenstein [1] denies stimulus any role in producing the word-frequency effect and instead assumes that, if the amount of noise present is the same, the percentage of correct responses to words in a given word-frequency class will be equal to the percentage of correct responses to words from any other word-frequency class having the same probability of response. According to this model, the probability of correct response p(C) is merely a constant function b of the probability that the response to a word from a given word-frequency class will be correct—that is, $p(S_i, R_j)$, where $i = j$. Because the stimuli have a flat distribution, all incorrect responses of a given word-frequency class will also have a flat distribution across stimuli from other word-frequency classes. Of course, as S/N increases, the probability that stimulus and response will agree in word-frequency class increases too, as does the probability of correct response.

By knowing that equal numbers of the stimulus words presented are taken from each word-frequency class—that is, $p(S_i) = 1/n$; by knowing the probability that a response will be from a given word-frequency class, $p(R_i)$; and by knowing a constant c, one can predict the increase in word-frequency effect, b/n.

In an experiment conducted to test the Brown and Rubenstein model, 64 printed English words five letters long were used as stimuli (see Table I). Sixteen words were selected at random from each of four word-frequency classes determined by Thorndike and Lorge [2]. Median word frequencies of the classes were 0.5, 5.0, 50, and 500 words per million. One, two, three, or four letters were deleted from each word, in the patterns summarized in Table II. Thus there were 256 different stimuli.

Four groups, of 40 undergraduate Ss each, filled deletions in the 64 different words. Each group saw a different deletion pattern for each word but worked on all deletion patterns. Ss were instructed to respond with 64 different words. This instruction reduced the number of common-word responses, flattened the distribution across word-frequencies, and provided a sharper test of the model.

Results are summarized in Tables III and IV, and in Figures 1 and 2. The following points are noteworthy. (a) The data determining the b values show an excellent fit; see, in Table III, the regression of p(C) on $p(S_iR_j)$ from the diagonal cells. (b) Plotting the distributions of incorrect responses from each of the four word-frequency classes gives a nearly flat curve; see the column distributions in Table III. (c) As Table IV shows, the predicted and the obtained regressions are very similar (the obtained slopes were taken from the column marginals in Table III).

TABLE I. WORDS USED ACCORDING TO WORD-FREQUENCY GROUP (WORDS/MILLION WORDS) (FROM REFERENCE 2)

0.5	5.0	50.0	500
inapt	envoy	grief	marry
shent	rigor	organ	voice
getup	probe	stove	smile
natty	niche	twist	month
caulk	chafe	porch	began
plumy	farce	queer	water
atomy	react	quote	heard
chump	hoary	merry	small
nares	silky	major	order
ascot	clamp	linen	price
faker	moody	shock	point
evict	booty	cruel	light
codes	lorry	brick	carry
julep	shyly	tooth	force
yodel	gruff	dying	heart
bilge	inlet	wreck	start

TABLE II. SAMPLES OF ALL DELETION PATTERNS

P____	RE___	HE_R_	SHOC_
_E___	_T_M_	_OOD_	PO_NT
__O__	___TE	_A_ER	_RUFF
___L_	*Y___L	*D_I_G	
*____T			

*These patterns were used in the actual experiment, but were not indicated since they were not comparable to the others in Table II.

TABLE III. PROBABILITIES (× 100) OF STIMULI (ROWS) AND RESPONSES (COLUMNS) BY FREQUENCY INTERVAL, p(C) is underscored.

	0.5	5.0	50	500
0.5	1.26, 0.12	7.19	10.08	6.09
5.0	0.73	5.60, 0.36	11.58	7.23
50	1.01	6.01	11.74, 0.60	6.17
500	0.69	5.89	11.38	7.11, 0.92
	3.69	24.69	44.78	26.58

(a) One letter given

	0.5	5.0	50	500
0.5	2.11, 0.56	7.43	6.78	5.28
5.0	0.89	8.04, 1.62	10.32	5.77
50	1.26	5.52	12.72, 3.90	6.21
500	0.32	4.87	9.87	10.60, 1.66
	4.58	25.86	41.69	27.86

(b) Two letters given

	0.5	5.0	50	500
0.5	9.38, 8.36	5.86	7.58	1.10
5.0	0.12	13.72, 10.65	6.96	4.18
50	0.72	5.65	16.63, 12.17	2.62
500	0.60	4.05	5.20	15.53, 11.53
	10.82	29.28	36.37	23.43

(c) Three letters given

	0.5	5.0	50	500
0.5	15.64, 15.52	4.24	3.28	0.92
5.0	0.00	22.96, 22.04	2.08	0.00
50	0.08	2.32	21.92, 20.40	1.04
500	0.04	0.48	3.72	21.28, 19.88
	15.76	30.00	31.00	23.24

(d) Four letters given

TABLE IV. PREDICTED (b/n) VALUES AND OBTAINED (COLUMN MARGINAL) VALUES OF REGRESSION SLOPES

	Number of Letters Given			
	1	2	3	4
b/n	0.012	0.066	0.132	0.207
b' (data)	0.012	0.085	0.140	0.355

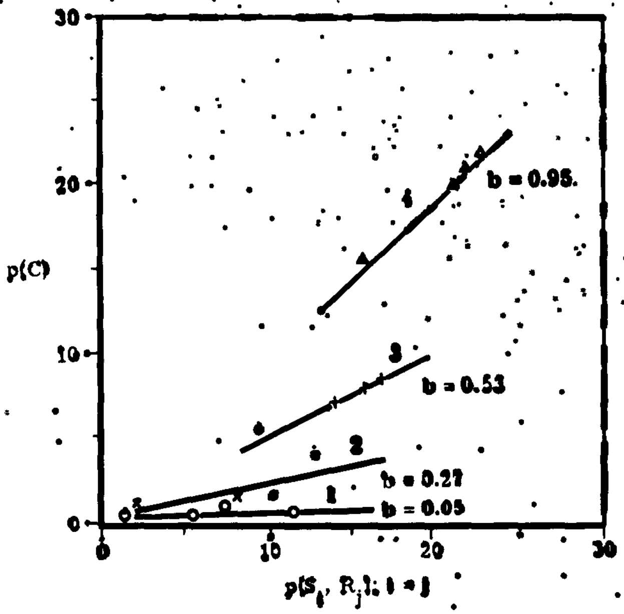

FIGURE 1. REGRESSION OF p(C) ON $p(S_i, R_j)$, FOR $i = j$. Internal parameter is the number of letters given in each word. p(C) = percentage of correct identifications, $p(S_i, R_j)$, where $i = j$, = percentage of response words agreeing in word-frequency class with stimulus words, $p(R_j)$ = percentage of response words in each word-frequency class.

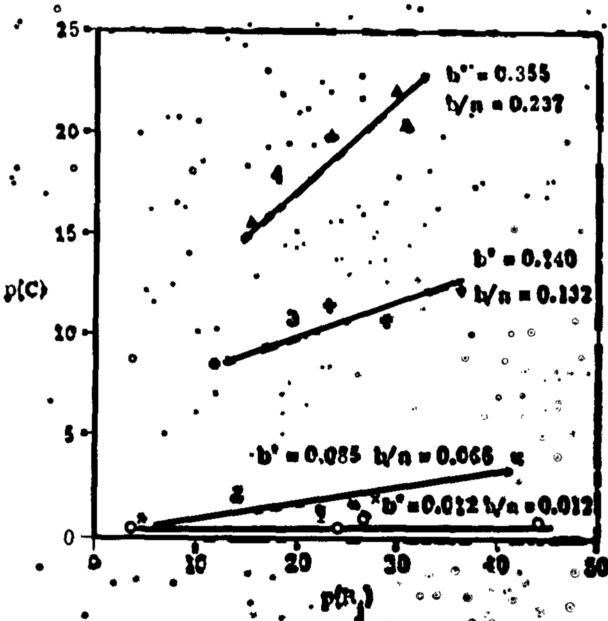

FIGURE 2. REGRESSION OF p(C) ON p(R). Internal parameter is the number of letters given each word. Slopes, b' and b/n, are the obtained and predicted values, respectively, given in Table IV.

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1. C. R. Brown and H. Rubenstein, "Test of Response Bias Explanation of Word-Frequency Effect," Science, 23 January 1961, Vol. 133, No. 3448, p. 280.
2. E. L. Thorndike and I. Lorge, The Teacher's Wordbook of 30,000 Words, New York, Teachers College, Columbia University, 1944.

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